

MANAGEMENT STUDIES OF THE COTTONTAIL RABBIT IN SOUTHWESTERN MICHIGAN

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The annual kill of cottontails (*Sylvilagus floridanus mearnsii*) by licensed hunters in Michigan is over 2,000,000 individuals. Little effort heretofore has been made to determine habitat requirements and develop management measures for this species, the two

most extensive previous studies being those of Trippensee (1934) and Allen (1938).

The present study was initiated in January, 1938, to evaluate effects of various management procedures. These included construction of brush piles and

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Allen, then Biologist in charge at the Swan Creek Station, contributed field records and supervision. U. S. Department of Agriculture and Works Progress Administration constructed brush piles and did other developmental work on the study area, F. J. Hodge being in charge. Betty M. Robertson identified the plants; field records were contributed by F. W. Stuewer and P. S. Baumgras.

artificial burrows, artificial stocking and distribution of artificial food during winter. In addition to studying populations in the various areas managed, the investigation included most phases of the life history of the rabbit.

The vicinity of the Swan Creek Wildlife Experiment Station near Allegan, Michigan, was chosen as the location for the studies because of the facilities available and the presence of a large acreage of sub-marginal land. The State of Michigan owns a considerable amount of such land with little value for agriculture. It has, therefore, been the aim of this investigation to find some practical means of increasing rabbit populations on such poor lands, and to make them more useful as public hunting grounds.

AREA STUDIED

The study was conducted chiefly in Valley Township (T2N, R14W, Secs. 5, 8), and Heath Township (T3N, R14W, Secs. 31, 32). The soil is Plain-field Sand ("Allegan Sand," Fippin and Rice, 1901) 30 to 60 feet in depth, with but little organic matter in the surface layer. The land is generally of third class, submarginal, or locally marginal (Veatch, 1933).

The topography is generally flat with the Kalamazoo River and its extensive bayous cutting through a wide meandering valley. Abrupt escarpments rise 50 to 60 feet and separate the sandy upland from the fertile river-bottom.

Climate. The annual precipitation is about 30 inches, including 60 inches of snowfall (Fippin and Rice, 1901). The mean annual temperature is about 48°F., the average annual maximum 95.5°F., the average annual minimum,

—12.1°F., and the average crop growing season is about 160 days (Leverett, 1917). Weather during 1938 and 1939 was not unusual.

History. Extensive forests were present in Allegan County when white men first settled there in 1831. The sandy plains immediately west of the city of Allegan then had extensive sparse growths of small "buckwheat pine" (Fippin and Rice, 1901). Most of this timber had been removed by 1870, and a shrubby growth of oak, sassafras, and poplar soon sprang up among the remaining pine. Some interspersions of beech, maple, and oak occurred along the borders of the pine forests. The heavier soils and lowlands in the county were originally covered densely with hardwoods. Cultivation was attempted after the pine forests were cleared, but the settlers, who usually owned 40 to 80 acres, could not make a living from the unproductive soil. In 1935, the U. S. Department of Agriculture began purchasing the submarginal lands in this area in the resettlement program and set it aside for conservation and recreation purposes.

Vegetation.—The trees on the sandy uplands are mainly oaks (*Quercus alba* and *Q. velutina*) up to about 10 inches in average diameter at breast height, with some sassafras, cherry, and dogwood. The deserted farm lands are slowly being invaded by weeds, dewberry, sassafras, cherry, and oaks. Local patches of "blow sand" have been partially stabilized by soil conservation measures. The composition of the present day vegetation is little different from that of 50 years ago, according to old settlers.

Individual study areas. Five 160-acre

upland experimental areas, here termed "quadrats," were selected in 1938, and designated according to the management measure applied; the fifth was held as a check area.

ARTIFICIAL BURROW AREA. The eastern two-thirds supports a dense stand of second-growth oak (white and black) 4 to 8 inches in diameter, and because of a general lack of shrubs is not well suited for rabbits. The cover on the remainder is favorable to rabbits, ranging from scattered oaks 3 to 6 inches in diameter to intermittent clumps of reproductive growth. Some New Jersey tea (*Ceanothus americanus*), wormwood (*Artemisia caudata*), and black cherry (*Prunus serotina*) is present.

STOCKING AREA. The main cover is of white and black oaks up to 3 inches (D.B.H.) and a few from 6 to 9 inches in diameter; the forest canopy is open. About 7 acres, once cultivated, are now covered with wormwood and grasses. Jersey tea is more abundant than on any of the other quadrats. The area contains more good rabbit cover than the other plots.

ARTIFICIAL FOOD AREA. This has a scattered stand of 4- to 8-inch oaks interspersed with moderate oak reproduction. About 15 acres, once cultivated, now support wormwood (Pl. 5, A) and scattered clumps of oak reproduction. The cover is comparable to that on the Stocking Area and on the western third of the Artificial Burrow Area.

BRUSH-PILE AREA. A dense stand of oak 5 to 10 inches in diameter covers 145 acres, the remainder being abandoned farm land with a dense growth of wormwood, a moderate amount of sassafras (*Sassafras albidum*), and a lit-

tle flowering dogwood (*Cornus florida*) predominating in the ground cover. The trees are larger and the forest canopy is denser than on the other study areas.

CHECK AREA. Oaks 5 to 10 inches in diameter cover the entire area which differs from the other study plots in not including any abandoned fields. Approximately half of it has almost no ground cover, but the remainder supports some small oak reproduction.

Hollow Trees and Burrows on Upland. A few oak trees (about 1 per 20 acres) have small hollows in their bases and such holes are often used by rabbits (Pl. 5, E). Hollow pine logs are often frequented, but their scarcity (about 1 per 40 acres) limits their value. Woodchucks and skunks are seldom found on the upland, and, accordingly, their burrows are usually lacking. One or more badgers living in the vicinity were not known to use more than three or four burrows. Evidently, the scarcity of ground squirrels provided little opportunity for badgers to dig in pursuit of such prey. A few upland sites lack suitable winter cover (burrows, brush piles, coppice); consequently, the rabbits migrate to the bottomlands during that season.

Food. The foods most available on the upland during winter were taken most frequently. The bark, twigs, and buds of white oak, flowering dogwood, sassafras, and Jersey tea were taken in liberal amounts (Haugen, 1942b).

METHOD OF STUDY

Information about the cottontail has been secured by live-trapping, shooting, necropsy, examination of burrows, tracking, scatology, and field observation.

Trapping technique. Forty-nine permanently numbered trap stations were established on each quadrat in a grid at 110-yard intervals; the outside rows of traps was 110 yards inside the quadrat boundaries. With this permanent spacing, the size of the area effectively trapped changes somewhat with change in the average size of the home range of animals living along the borders. During summer most of the rabbits taken are young with an average range of 9.3 acres (Haugen, 1942a) so that the entire quadrat of 160 acres will be effectively trapped. The average home range of the population increases above 10 acres (a cruising radius of about 110 yards) during fall, winter, and early spring, and then the area effectively trapped was slightly larger than the 160-acre study plots.

Live-traps (Pl. 5, C) were set near the most suitable cover within 50 feet of the "station," usually with the opening toward the base of a clump of bushes or a tree. A combination of ear-corn, rolled oats and apple bait was used, and the traps were visited each morning. The rabbits taken were closely examined for ectoparasites and breeding condition, and a series of measurements was recorded (Haugen, 1942b). When each was first captured it was marked with a numbered "fingerling" or butt-type ear-tag. Tag numbers of rabbits previously marked were recorded with other data noted.

Reliability of census methods. One of the most difficult problems in game management is that of checking population density. Investigators have met this difficulty with a variety of methods, most of them extensive in nature. Estimates of populations have been ob-

tained by direct observation, fecal pellet count, tracking, shooting, and trapping. Tracking, pellet counts, and direct observation give an index to the population, but the results are often limited in application and difficult to interpret. Tracking is limited to seasons of snow, or to local dusty areas. Shooting obviously is disadvantageous in that the population is sacrificed, thereby preventing a recount.

Live-trapping and marking requires considerable labor and expense, but if properly done gives a reliable index to the number of rabbits present. The size of quadrat, type and location of traps, bait, weather, dispersal, migration, individual (rabbit) behavior, and the length of the trapping period all influence the number of rabbits caught.

The size of the quadrat to be censused has an important relationship to the results obtained. Bole (1939) found that as the size of a quadrat was increased, the apparent population density of small mammals decreased. The chance for drifting animals to move across an area and be counted is proportionately reduced as the size of the quadrat increases (Dice, 1938) because the area increases at a greater rate than the perimeter. The relationship between size of area censused and size of home range of the species studied is particularly important. The area censused obviously should be at least several times that of the average home range. The quadrats in this study were about 7 times the average home range of an adult female cottontail (Haugen, 1942a) and consequently considered adequate for population study. The type of traps employed, their spacing, and the bait technique were standardized, and are

believed to have been equally efficient at all times.

Five juvenile males, 16 adult females, and 26 adult males reappeared in the traps after an absence of one or more

method does not sacrifice individuals and population density can be rechecked from time to time. It also allows a simultaneous study of the life history and populations.

Table 1.—AVERAGE DISTRIBUTION OF "NEW" CAPTURES AND RECAPTURES OF INDIVIDUAL COTTONTAILS ON SIX STUDY AREAS, AS TO THE RELATIVE POSITION OF DAY WITHIN TRAPPING PERIOD; 1938-1939.

Day in trapping period	Number of trapping periods	For each day of trapping period				
		Total new captures	Average of new individuals	Total recaptures	Average of recaptures	Total catch
1	46	131	2.85 (100%)	0	0.0	131
2	46	79	1.72 (84%)	15	.3	94
3	46	67	1.46 (61%)	43	.9	110
4	46	58	1.26 (56%)	46	1.0	104
5	46	45	.98 (47%)	50	1.1	95
6	45	48	1.07 (35%)	88	2.0	136
7	44	34	.77 (31%)	75	1.7	109
8	43	33	.77 (29%)	79	1.8	112
9	43	29	.67 (25%)	88	2.0	117
10	42	30	.71 (29%)	73	1.7	103
11	38	25	.66 (24%)	78	2.1	103
12	35	20	.57 (19%)	88	2.5	108
13	33	11	.33 (14%)	69	2.1	80
14	31	19	.61 (25%)	57	1.8	76
15	24	6	.25 (13%)	39	1.6	45
16	22	8	.36 (15%)	45	2.0	53
17	20	10	.50 (18%)	45	2.2	55
18	16	4	.25 (12%)	30	1.9	34
19	12	10	.83 (32%)	21	1.7	31
20	6	1	.17 (11%)	8	1.3	9
21	5	4	.80 (18%)	18	3.6	22
22	5	4	.80 (18%)	19	3.8	23
23	5	2	.40 (25%)	6	1.2	8
24	4	3	.75 (17%)	15	3.7	18
25	4	1	.25 (14%)	6	1.5	7

immediately previous census periods. Chances for reappearance decreased as the length of the absence increased. Some of these animals may have temporarily shifted their ranges.

Live-trapping has several advantages over other census methods. The recapture of ear-marked individuals frequently gives evidence as to whether they are resident or transient. The

Duration of trapping necessary to capture all individuals. A steady decline in capture of new rabbits (those first handled during any given census period) occurred from the first to the fifth day of a census period (Table 1; Fig. 1). The diminishing yield of new individuals was especially rapid during the breeding season and fall, but less so during winter. From the 6th to the 10th

days of a trapping period, the decline was small. After the 10th day, the daily catch of additional individuals continued at an average rate of about one new rabbit per 2 days of trapping. Probably these were mainly non-residents (drifters) which were taken in fluctuating numbers.

During winter, daily catches of new individuals were distributed rather evenly over the first 9 days of a census. After the 9th day in winter trapping, the percentage catch of new individuals decreased sharply and few new individuals were taken after the 10th day. Evidently, rabbits have more securely established ranges in this season.

The trend of the diminishing daily yield of new individuals (Fig. 1) is

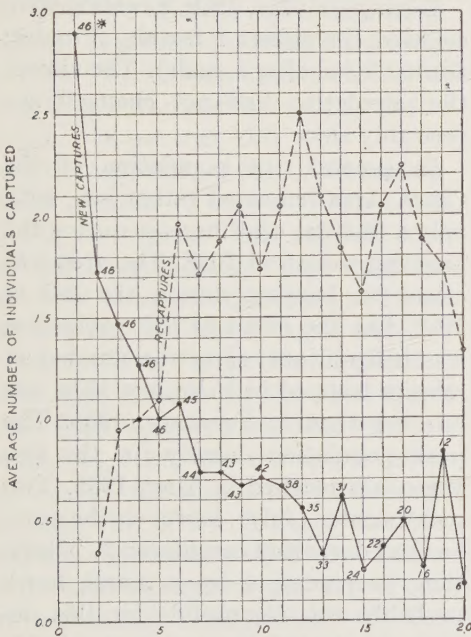


Fig. 1. Average daily catch of cottontails per 160-acre quadrat for first 20 days of trapping based on records from six quadrats; *number of trapping periods on which average is based.

similar to that found by Bole (1939) and Burt (1940) for smaller mammals. Their skew curves (rapidly decreasing yield of individuals) declined sharply from the first to the third days of

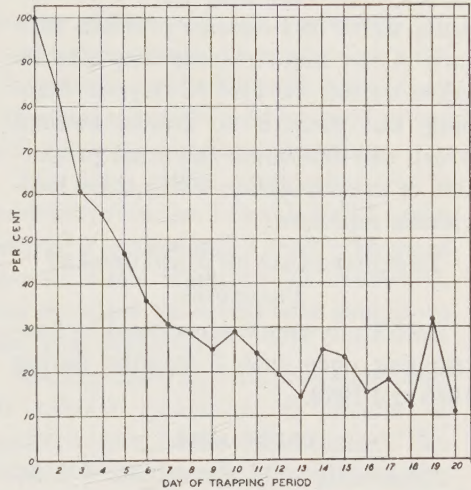


Fig. 2. Percentage of new individuals among the total catch of cottontails for any given day of a trapping period (all ages and both sexes combined).

trapping, then continued at a low but fairly constant level.

Under the conditions of the present study ten days of live-trapping apparently were sufficient to census an area; consequently, all population figures given here are based on ten days of live-trapping. A census by this method will not be entirely accurate, but censuses on different areas of generally similar size, or on the same area at different times should be comparable. Due to the geometric spacing (grid pattern) of traps, more time was required to census the areas than if the traps had been more strategically placed.

Non-resident rabbits. Rabbits without established ranges on an area, but which

moved on across or off an area were termed "drifters." The majority of new individuals taken after the 10th day of trapping during the breeding season and fall period were probably drifters (Fig. 2), although a few may have been residents which had escaped previous capture. A few non-residents may also be taken during the first 10 days of trapping, but there is no known method which will determine the exact proportion of the population which these individuals represent.

EFFECTIVENESS OF MANAGEMENT PRACTICES

Each study area was censused by live-trapping once each 3 months during 1938 and 1939.

CHECK AREA

Apparently only six rabbits (2 female, 4 males) occupied this area at the original census in late February, 1938. Three months later (June 17-July 2) only seven (1 juvenile male, 2 female and 4 male adults) were taken. It is not surprising that the population had not increased appreciably because at each census only 2 adult females were found, both occupying ranges partly outside the area.

By the fall of 1938, the population had increased to 12 (juveniles: 3 females, 2 males; adults: 3 females, 4 males). Of the adults, one female and one male captured may possibly have been physically mature young of the year.

The late winter (February, 1939) population was five (2 females and 3 males). At least three of them occupied "borderline ranges" along the margins; one female and a male ranged into a leather-leaf bog which provided the best

cover available either in or adjacent to the area.

During May, 1939, 16 were secured (juveniles: 2 females, 2 males; adults: 5 females, 7 males). Cottontails were then more numerous on this area than at any other season during 1938 or 1939.

A July, 1939, census accounted for only 7 rabbits (juveniles: 3 females, 1 male; adults: 2 females, 1 male), less than half those present in May. Six adult males and 3 adult females present in May were not retaken at this time. A marsh hawk nesting in the nearby leather-leaf bog perhaps was partly responsible for the apparent decline in numbers. Hind feet of juvenile rabbits were frequently found at the hawk's nest.

During October, 1939, 9 rabbits were counted (juveniles: 1 female, 5 males; adults: 2 females, 1 male). The size of the population had not changed appreciably since July.

In general, the population of the Check Area remained rather low, with only a 58.3 per cent increase during the breeding season of 1938. The area was closed to hunting during the fall of 1938, but the effect of this protection was insignificant, since the number of rabbits trapped in February 1939 was one less than in February, 1938. The peak population density for the two years was reached in May, 1939. Two months later (July), however, the number had decreased considerably. Migration, or predation by a marsh hawk probably was responsible for this decline. Evidently, the area had suitable cover for only about 2 adult female home ranges. At no time did the population reach a greater density than 1 rabbit to 10 acres of quadrat area.

ARTIFICIAL FOOD AREA

Nine rabbits (3 females, 6 males) were counted during late April, 1938. In late August, 1938, the population was 11 (juveniles: 3 females, 4 males; adults: 1 female, 3 males). Accordingly, only 2 more were present than during the previous spring. Only one of three females present during spring of 1938 was still there in the following August and the range of this one extended outside the area. Perhaps predation or emigration was responsible for the disappearance of the other two females.

The October, 1938, population was 16 (juveniles: 4 females, 5 males; adults: 3 females, 4 males). The three adult females taken were unmarked and two of them were never retaken. It is possible that two of these seemingly adult animals were large juveniles born early in 1938. The fall population was seven more than in the previous spring, an increase of 78 per cent.

At the beginning of the 1939 breeding season (March 1) only 7 (1 female, 6 males) were taken. This number does not differ significantly from those on the other areas at this season and was two less than present in April, 1938.

One hundred ten screen hoppers located grid fashion on the Food Area were filled with scratch feed on December 14, 1938, and were replenished throughout the winter until February 22, 1939 (Pl. 6, B). A supply of this food was constantly available to rabbits on the area throughout the winter, but the cottontails disappeared from the area except along the escarpment edge. A few individuals evidently were living in the adjacent bottomland, returning to the top of the escarpment to eat at the nearest feeders, and then returning

to the lowland for cover. Allen (1939) found that cottontails regularly patronized feeding stations put out for birds. On the basis of the evidence here presented, however, it is concluded that an abundance of scratch feed in an area during winter will not necessarily increase the number of resident rabbits. Cottontails evidently will forsake an abundant supply of food for good cover, if the two are not found together.

The June, 1939, population was 9 rabbits (juveniles: 1 female and 1 male; adults: 6 females and 1 male). Three of the six adult females were unmarked, but the other three had been caught on the area previously.

During mid-July this area supported 21 rabbits (juveniles: 6 females, 7 males; adults: 8 females, no males). The population of breeding females on the area at this time was the largest noted there during 1938 or 1939. Two must have immigrated after June, 1939, at which time only six adult females were present. One of the immigrant females was released on an area one half mile distant in January, 1939. She roamed considerably during the breeding season, and did not appear to establish a fixed home range. No adult males were secured during the ten-day census, but it is almost certain that at least some of the four males taken in nine days of post-census trapping were residents, that had avoided capture during the regular census period.

During late October, 1939, 22 individuals (juvenile: 10 females, 12 males; no adults) were caught. This number is larger than at any other time during 1938 and 1939. The absence of adult rabbits of both sexes is unusual. Probably the majority, if not all, mature in-

dividuals had left the area, or avoided capture at this time. My supposition is that they had gone into the adjacent bottomland, which was used considerably by cottontails during the previous winter.

In general, cottontails of the Food Area did not remain to utilize the scratch feed during winter. A few fed at the stations near the edge of the escarpment, but were evidently occupying the bottomland coverts most of the time. The breeding population following the winter feeding was nine animals. They had benefited by protection from hunting the previous fall, and had access to an abundance of scratch feed during the winter of 1938-39. Despite this advantage, the 1939 spring population consisted of two fewer rabbits than during the spring of 1938. The late summer and fall population in 1939 increased, however, until late October when it was 37.5 per cent larger than during the fall of 1938. This increase in resident animals to one per 7.3 acres of quadrat area was correlated with increase in the number of breeding animals on the area in July, 1939, but cannot be traced to artificial feeding during the previous winter.

ARTIFICIAL BURROW AREA

During April, 1938, when first censused, 16 rabbits, (7 females, 9 males) were captured, the largest population on any management area during the spring of 1938. Two of the adult females had been released on the adjacent area (Stocking) two weeks previously. One adult male was taken for autopsy because of a mange-like condition of its skin, and one adult male was killed in a trap by a weasel.

On May 9 and 10, 1938, 112 artificial burrows were constructed and a month later rabbit hair was found in 36 burrows (32 per cent). Hairs found in the burrows were identified by the aid of a reference collection for field use (Haugen, 1939).

Between July 25 and August 6, 1938, 19 rabbits (juveniles: 5 females, 6 males; adults: 4 females, 4 males) were taken, three more than present during the previous spring. The actual increase, however, was five, because two of the spring residents were removed during that census. No signs of mortality were noted during the summer.

The fall population (November, 1938) consisted of 17 rabbits (juveniles: 5 females, 6 males; adults: 4 females, 2 males), one more than present the previous spring, but two-thirds of the population were juveniles. This lack of increase may have been due to mortality, excessive emigration, or in part to trap-shyness by adults in autumn.

During January, 1939, only 6 rabbits (3 females, 3 males) were taken. Part of the decrease may have resulted from an unknown amount of poaching just previously. Live-trapping at this time failed to capture a previously marked rabbit which was taken from one of the burrows during the census. Three other individuals taken from burrows two weeks previously were not retaken during the census, or on subsequent burrow checks. Each cottontail taken from burrows or by live-trapping in the area during January, 1939, had been ear-tagged during some previous census.

Artificial burrows were used by rabbits considerably between December 28, 1938, and January 27, 1939. During this time 9 cottontails (6 females, 3

males) were taken 12 times from ground dens. One of them was taken from one of two holes examined on January 25. All burrows were examined as a group five times during this period and the presence of rabbit tracks was considered as evidence that they had been used. On January 3, tracks of cottontails were found at the entrances of 33 (29.5%) of the 112 holes. Some burrows had beaten paths leading to the entrance, and it was not uncommon to find the tracks of a single animal entering two holes in one night.

At least six individuals occupied the Burrow Area during January, 1939, whereas the adjacent Stocking Area had only two. This difference in population was obvious both from trapping records and relative numbers of tracks. Where artificial burrows were accompanied by suitable cover and food (all-age stand of oak, with some underbrush), rabbits remained on the upland during winter. Ground holes located in the open or among large trees with a dense forest canopy were not used during winter because rabbits migrated from those localities. This evidence on the use of burrows according to location accords with that by Allen (1939) in southern Michigan.

During April, 1939, 12 rabbits (5 females, 7 males) were found on the Artificial Burrow Area. Six of them were also present in January; the others had evidently entered the area after the winter census. Four of the newcomers had been marked on the quadrat the previous fall but were absent during winter, and the other two were taken for the first time. The spring breeding population in 1939 accordingly was only three-fourths as large as that in

1938 (16 rabbits). Since two of the females in the 1938 spring census had immigrated soon after being released on an adjacent quadrat they probably should be disregarded in computing the population. Accordingly, there was an actual difference of only two rabbits in the spring populations of 1938 and 1939 (14 and 12 respectively).

Artificial burrows were used considerably and kept rabbits on the upland during the winter of 1938, and 1939, but did not bring about an increase in population during the following spring. Four juveniles were found in artificial burrows in May, 1939, but no adults were secured from burrows except during inclement winter weather.

In early August, 1939, 11 rabbits (juveniles: 4 females, 4 males; adults: 2 females, 1 male) were trapped, and during November, 1939, 14 were captured (juveniles: 6 females, 7 males; adults: 1 male). The catch of new individuals at this time was spread rather evenly over the entire census period. It appeared as if rabbits then were trap-shy, but the actual cause of delay in captures is unknown. Such a delay makes a 10-day census appear incomplete. More cottontails, however, were on the area at this time than at any other time during 1939.

During July and August, 1938, more rabbits (one per 8.4 quadrat acres) were found on the area than at any other time, although the artificial burrows had been present for only two months.

The population of the Artificial Burrow Area was generally higher during 1938 than during 1939. This is surprising, because the breeding population of 1939 had been protected from legal hunting, and the burrows had held

several rabbits on the tract throughout the winter of 1938-39. During 1939, weasels on the quadrat increased and they frequently visited the live-traps, to kill or injure captive animals. At no time, however, was a rabbit known to have been killed in an artificial burrow. Burrows were readily used by cotton-tails as winter cover, but their presence did not increase the fall population available for sportsmen to harvest.

ARTIFICIAL STOCKING AREA

Thirteen rabbits (6 females, 7 males) were taken on this area in March, 1938, before any stocking was done. And then 11 additional rabbits (6 females, 5 males), live-trapped at the Mason Game Farm, were released on the plot. All appeared to be in good condition. The combined resident and released population at the end of March was 24 (12 females, 12 males).

In late July, 23 rabbits (juveniles: 9 females, 9 males; adults: 3 females, 2 males) were captured on the area. Four of the adults were local residents and the fifth was an introduced male. Seemingly, the other 10 introduced rabbits had left the area, were dead, or were avoiding capture. Of those introduced, two females and one male were recaptured on an adjacent area during spring and summer. Allen (1939) transplanted seven rabbits in an area under intensive study, and found that only one remained near the point of liberation. Of 51 mice (*Peromyscus leucopus noveboracensis*) which were moved 160 to 365 yards, Burt (1940) noted that only 2 per cent stayed at the point of release and $31\frac{1}{2}$ per cent were not retaken again. Obviously then, the restocking of a given tract does not

necessarily increase the future resident population of that area.

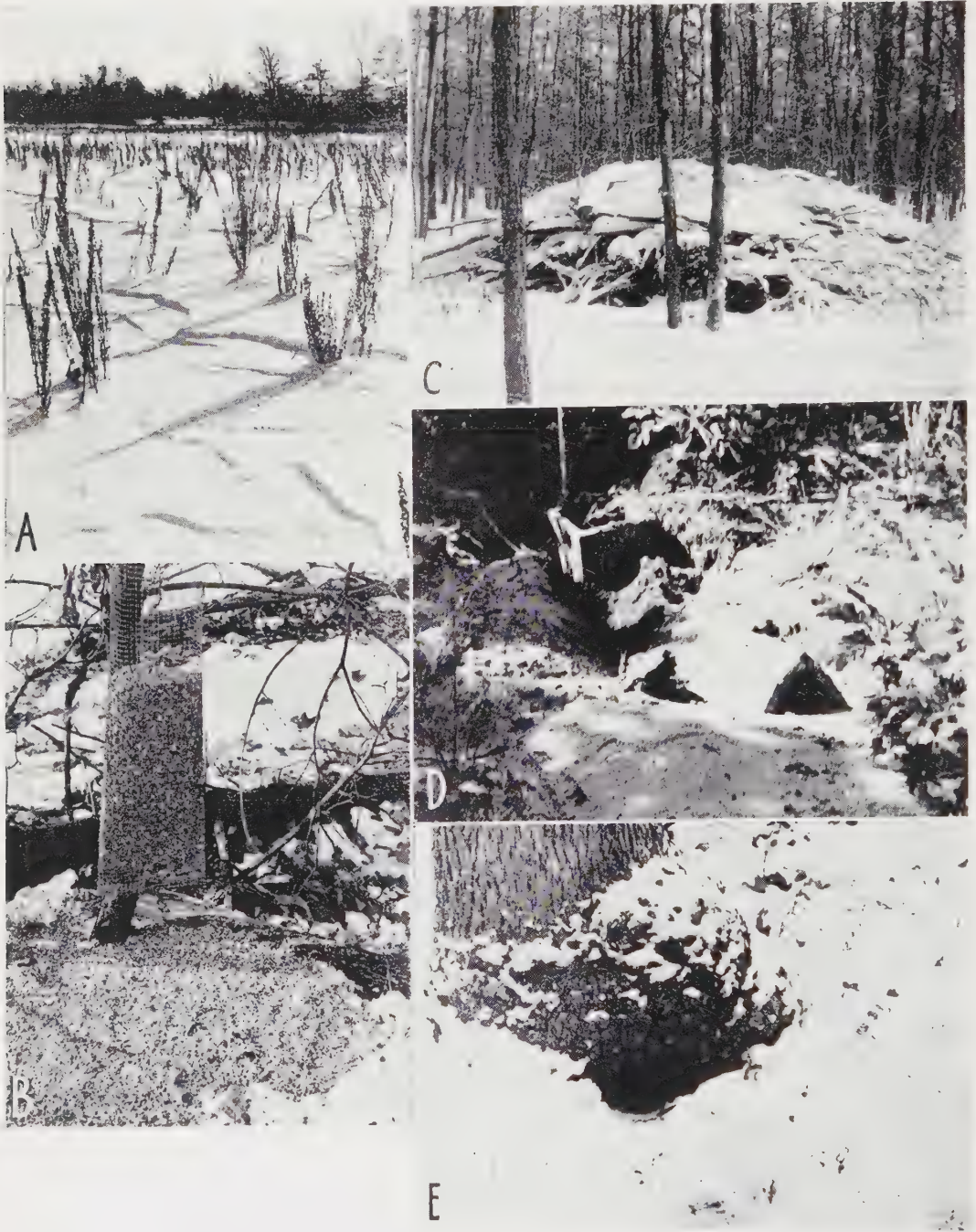
During November, 1938, 23 rabbits (juveniles: 7 females, 13 males; adults: 2 females, 1 male) were trapped. The plot was closed to hunting during the fall of 1938, consequently the population should have been normal.

In January, 1939, only two rabbits, a female and a male were trapped, and tracks were scarce. Unfortunately, the area had been illegally hunted by several men with two or more dogs on December 25, 1938. Very likely, several rabbits were bagged because most of the poaching occurred in the most densely populated part of the quadrat. Not all of the rabbits absent during the January census, however, had been shot. Some must have migrated from the area, because six from the fall population reappeared the following spring.

The population increased from 16 individuals in April, 1939, to 35 (juveniles: 14 females, 17 males; adults: 4 females) in August 1939. Eleven breeding females occupied the area during the spring. Four of these females were found pregnant 4 times; two, 3 times; two, 2 times; and three, 1 time during the 1939 breeding season. Undoubtedly, there were other pregnancies not detected among these females. If all known pregnancies had been successful, had been of average sized litters with complete survival, and had not dispersed previous to the August census, then 156 young should have been present at that season. If the population density of the surrounding area were equal to that in the area, dispersal probably would not have had much effect on the number of young present, because an equal number of young



A. Grazed woodlot with browse line. Cattle have destroyed ground cover necessary to wildlife. B. Release cutting should be done in this stand of mature timber. C. Live-trap used in study. Traps covered with $\frac{1}{2}$ -inch hardware cloth are better and were used almost exclusively during the second year. D. Two years after this strip was cleared, the oak coppice and flowering dogwood were large enough to give good cover and food for cottontails. E. Pine planting frequented by cottontails more often than the dense-crowned stand of large oaks beyond. F. This dump forms excellent escape cover for cottontails.



A. Abandoned field covered with wormwood (*Artemisia caudata*). B. One of the 110 artificial feeding stations; much used by squirrels, and songbirds, some by opossums, but little by rabbits. C. One of the 112 brush piles constructed on the Brush-pile Area and used considerably by rabbits during inclement weather. D. Artificial burrow partially excavated by a canine predator. Such burrows were used considerably by rabbits during bad weather. E. Hole in base of white oak used by adult female cottontail during stormy weather.

would have left and entered the area. In August, there were 35 rabbits; the 31 young in this population indicate a possible known survival rate of only 1 young rabbit from 5 embryos.

In November, 1939, only 15 rabbits, all juveniles (10 females, 5 males) were taken, less than half the total present during August. This reduction probably resulted from emigration and mortality, as hunting was prohibited.

Liberation of 11 rabbits on the Stocking Area (13 known residents present at time) in March, 1938, did not significantly increase the numbers present during the following fall. Six subsequent censuses taken during the ensuing 19 months verify this conclusion. Poaching and migration helped to reduce the 1938 fall population until only two rabbits remained in January, 1939. Migrating animals repopulated the area during the spring of 1939. During the summer of 1939, the number increased to one and one-half (35 animals) that of the known summer population of 1938. The larger summer population in 1939 cannot be attributed to restocking in the spring of 1938. On the basis of the number of individuals present in 1939 and the known rate of reproduction of the breeding females taken on the area, it is believed that not over 1 rabbit in 5 survived until late August.

BRUSH-PILE AREA

When first censused in March, 1938, only 4 rabbits (1 female, 3 males) were taken. During April and early May, 1938, 112 piles ($4\frac{1}{2}$ ft. high and 12 to 14 ft. in diameter) were scattered at 110-yard intervals in a grid pattern throughout the area (Pl. 6, C). In June, 1938, a considerable increase in rabbits

was noted, 14 individuals being present (juveniles: 1 female, 3 males; adults: 5 females, 5 males). The adult population apparently had more than doubled since March. The increase in breeding animals probably resulted from an influx of individuals during spring, and perhaps the newly constructed brush heaps had served as an attraction.

In late September, 14 were trapped (juveniles: 1 female, 9 males; adults: 2 females, 2 males), only two-fifths as many as present in June, but the juveniles had increased from four to 10. The population then was equal to that during June, but with an increased percentage of juveniles.

In December, 1938, only five were secured (juveniles: 3 males; adults: 2 males). Three of them had not been taken previously. The population had apparently decreased to about one-third the density in June and September.

On four occasions between December 23, 1938, and February 3, 1939 the brush piles were checked for signs of use. Cottontail tracks were found in or around 62 (55.4%) of the piles. During severe weather rabbits remained in the brush heaps except to venture out a few yards, feed, and then return to cover. During deep snow and stormy weather, eight rabbits fed outward from the pile for an average distance of 26.4 yards. In milder weather they often moved back and forth between 2 or more piles. Rabbit tracks were more numerous in this quadrat during the winter of 1938-39 than in any other study plot except the Artificial Burrow Area.

Where heaps of brush were available, a larger number of rabbits than usual

remained on the upland during winter. In February, 1939, 10 adults (2 females, 8 males) were taken on the Brush-pile Area. The preponderance of males taken indicates there may have been an influx of them. Adult males have a larger home range than do females, and it is therefore possible that more males found the added cover and remained to utilize the added security.

In May, 1939, 13 rabbits were taken (juveniles: 2 females, 2 males; adults: 4 females, 5 males), two more females and three fewer males than in February. The two new females were pregnant, and were probably residents of the quadrat.

A considerable reduction in population occurred between May 25 and July 10, 1939, at the end of which time only four rabbits (juvenile: 1 female; adults: 2 females, 1 male) remained. At this time, rabbits were taken in usual numbers in other study areas. Perhaps weasels or the pair of nesting broad-winged hawks contributed to the decrease in early summer population. A considerable amount of fur from juvenile rabbits was found beneath the hawk nest. The influence of these raptors probably decreased after July 20 when their young left the nest.

Between July and October, 1939, the population increased and 16 were taken during October (juveniles: 9 females, 4 males; adults: 3 males). This was the largest population found on the area in either 1938 or 1939. The increase in immature cottontails to 13 possibly was due to an influx of young, or to further reproduction by the two females present in July. In any event, the increase occurred after the departure of the nesting hawks, but the actual source

of the fall population remains unknown.

In general, it appears that the average populations of the Brush-pile Area were comparable during 1938 and 1939 (brush piles constructed in May, 1938), except for the temporary reduction during July, 1939. The presence of weasels and a pair of hawks coincided with this temporary drop in population. No precise measure of predation, however, was secured. Brush piles were used considerably by the rabbits during inclement weather, and were undoubtedly instrumental in retaining a larger than average number on the area during winter; their ultimate effect on the population of huntable rabbits, however, remains uncertain.

DISCUSSION OF POPULATIONS

The data on populations for the five management areas in 1938 and 1939 are believed to be comparable. Major variations in the number of rabbits resulted from predation, migration, and poaching. The average number of cottontails on the five areas during 1938 increased steadily between June and November (Fig. 3), and was greatest from September to November.

During 1938 the management measures practiced were provision of artificial brush piles and burrows, and stocking. No subsequent increase in number of cottontails was noted during that year.

During the summer and fall of 1939, the populations on the areas were, on the average, not greatly different from those of 1938 (Fig. 3). A larger average number should have been expected in 1939, because, except for a little poaching, the study plots were not hunted in 1938. It is believed that the average

1939 fall populations would have been slightly higher if predation had not increased.

Irrespective of management measures, the greatest number of rabbits were among scattered growths of copice and shrub reproduction. Rabbits were seldom noted in large open areas or in dense stands of mature timber with a complete forest canopy (Haugen, 1942b).

EFFECTIVENESS OF MANAGEMENT

Cottontails were scarce on the upland during winter because they migrated to the nearby lowland coverts. Many of the marked rabbits, however, reappeared on the upland in February and March. Where artificial burrows and brush piles were available along with moderately good tree and brush pile cover, the rabbits remained on the upland in greater numbers than in similar areas lacking this added artificial cover. Consequently, the addition of holes or brush piles reduced the concentration in the lowland coverts. Such concentrations ordinarily increase the vulnerability of rabbits to predation and to mortality by flooding. Considerable mortality by drowning of *Sylvilagus aquaticus littoralis* was found in Louisiana by Svihla (1929). Disease and parasitism, as well as vulnerability to predation are usually increased in importance among heavy concentrations of animals. Management measures which keep the rabbits dispersed on the upland should therefore be desirable.

Distribution of artificial food was not effective in retaining rabbits on the upland during winter. Instead, they seemed to withdraw into the bottomland at the advent of winter, although

a few returned intermittently to eat the scratch feed provided. No evidence was found to indicate that artificial feeding was effective.

By introducing 11 rabbits on the Artificial Stocking Area of 160 acres in

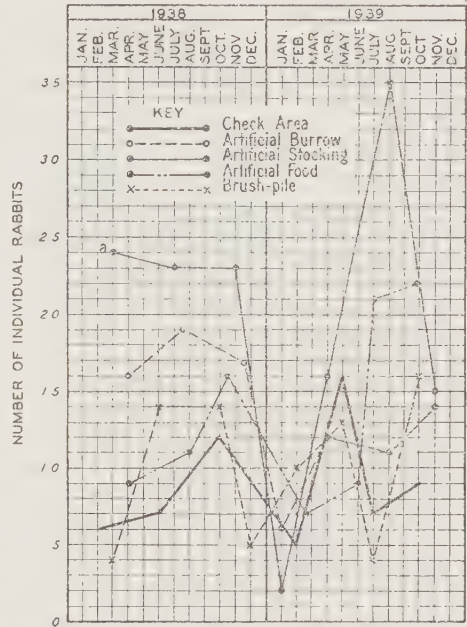


Fig. 3. Resident cottontail populations of six 160-acre management areas during 1938 and 1939; a, 13 resident and 11 transplanted; no further planting.

March, 1938, the potential breeding stock was raised from 13 to 24 cottontails. The following fall only 23 were present, indicating a failure in the restocking. The peak population of 35 there was found in 1939, during which year no cottontails were released. More breeding females, however, were present during 1939 than in the previous year. It is certain that this increased population did not result from restocking in the previous year, because most

of the transplanted rabbits disappeared. The availability of better rabbit cover on the area was probably responsible for the greater number of rabbits than were found in the other areas of equal size.

COSTS OF MANAGEMENT

Employment of any management measure can be justified only when that measure so increases the population of the species managed that the value of the increase exceeds the cost of development. The latter value in one or more economically important species is intangible, and difficult to measure. Measures such as artificial burrows, stocking, winter feeding, and brush piles have been used in an attempt to evaluate their usefulness as management measures for cottontails.

Artificial feeding. Scratch feed consisting of 41 lbs. cracked corn, 34 lbs. oats, 13 lbs. wheat, 3 lbs. buckwheat, and 3 lbs. Kaffir corn was distributed on the Food Area during the winter of 1938-39. At an average value of \$0.74 per bushel, the 53.62 bushels of feed distributed cost \$39.68. Few cottontails remained on the upland to make use of the food and no increase in population resulted. Grouse, fox squirrels, deer, and songbirds used the feed extensively, but it is difficult to evaluate fully the ecologic effect of the feeding experiments for animals other than rabbits.

Brush piles. One hundred twelve heaps of brush (12 to 14 feet in diameter and about 4.5 feet high) were placed in the Brush-pile Area (Pl. 6, C). The foundations were made as follows: a log about 8 or 10 inches in diameter and 3 or 4 feet long was first placed and 5 or 6 longer and more slender pieces were

radiated in spoke-like fashion from the center piece on which the inner ends rested. Brush was then placed over this circular or dome-shaped bottom structure. The 112 brush piles were constructed by a local W.P.A. project at the rate of one pile per 9 hours of labor. At the prevailing rates for W.P.A. labor each cost \$3.28, and the expense of developing 160 acres was \$367.36. If the piles remain useful for 6 years, the average annual cost is \$61.23 per quarter section.

As previously noted brush piles retained more than an average number of rabbits on the upland during the winter and it is felt that their value should be further studied. From the cost of development and the scarcity of rabbits noted in this study, it is obvious that brush piles if used for cottontail management must be obtained as a byproduct of wood cutting, or by volunteer labor. Timber cutting in addition to providing brush heaps leads to and increase in shrubby vegetation where rabbits are most abundant (Haugen, 1942b).

Artificial burrows. One hundred twelve artificial burrows were constructed from scrap lumber and placed within a 160-acre area. Each consisted of a 54-inch tunnel and a nest box. The tunnel was made from two 8-inch boards, nailed together along one edge to form an inverted trough, which was buried in a trench (Pl. 6, D). The entrance end was level with the ground surface and the lower end opened into the nest box 18 inches below the surface. The nest box was 12 inches square by 18 inches high, with a removable lid resting on cleats at a point 6 inches below the top of the box. The nest

box was set into the ground so that its top end was flush with the surface.

The 112 burrows were constructed and buried at a labor cost of \$0.47 each. The cost of developing 160 acres was therefore \$52.64 (144 man-hours of labor). If the burrows last 4 years, the average annual cost of development would be \$13.16. This may be too high to be practicable but more nearly approaches a reasonable figure than did that of development with brush piles.

Artificial stocking. Eleven rabbits were released on the Stocking Area in late March 1938. Gerstell (1939) found the cost of capturing, transporting, and releasing local cottontails in Pennsylvania to be \$0.35 each. At this rate, the restocking of 11 rabbits probably cost a minimum of \$3.85. This expense seems reasonably low, but the release of cottontails had little or no effect on the ultimate population the following fall. A second remote area was stocked with 68 wild cottontails with no resulting increase in the local population (Haugen, 1941). Such findings are in agreement with the observations of Gerstell (1937) in Pennsylvania. As a rule, the released rabbits roamed considerably, and they may have caused a small increase in the general population of the region, although such an influence was not detected.

GENERAL DISCUSSION

Female cottontails in Michigan often produce four litters in a season and each litter averages 5.4 young (Haugen, 1942b), so that one female may bear 20 or more young per season. Factors other than reproductive rate therefore, must limit the cottontail populations in the region.

Competition for home sites or territories by adult breeding females may at times limit cottontail populations. The areas studied usually contained some apparently suitable habitats in which breeding females were not taken, so that there seemed to be an excess of available home sites (Haugen, 1942a). It seems, therefore, that the cottontail populations studied were not limited to any great extent by competition for nesting sites. Females and young which occupied the least favorable habitats probably suffered the greatest mortality by predation, as such habitats averaged fewer rabbits than more favorable ones.

The main factor limiting cottontail populations on the study areas under present conditions of food and cover is evidently mortality, and not emigration or inadequate reproductive rate. Intensive study of the Stocking Area revealed that most of this mortality was among juveniles; only about one young in five survived until fall. It is not known that disease or parasites caused any appreciable loss among the local wild cottontails; on the contrary, heavily parasitized individuals often appeared fat and healthy. In this study, the only two known deaths from disease were among captive rabbits. Tularemia has not yet been found in the vicinity of the station.

Migration of cottontails to the lowlands, for cover and the resultant concentration there during winter probably increased mortality by predation. The population on an area supplied with a superabundance of artificial food migrated similarly. Rabbits on areas developed with brush piles, and with artificial burrows, however, did not

migrate so readily, but remained to utilize such cover.

Predator pressure is evidently exerted throughout the year, but no precise measure of predation was obtained. The area seemed to have a predator population slightly greater than the average in southern Michigan.

The upland soil is sandy and poor, producing little succulent food and cover. The growth of these necessities is further limited by a lack of sunlight, screened out in many places by a dense forest canopy. As a result of food and cover deficiency the sandy upland areas are little used by other prey species such as ground squirrels (*Citellus*) and chipmunks (*Tamias*). Woodchucks and skunks are only occasionally present and meadow mice (*Microtus*) were not taken on the upland. Accordingly, the cottontail, opossum, fox squirrel, and wood mouse (*Peromyscus leucopus*) probably bear the brunt of predation. Opossums and other species may also feed on young cottontails still in the nest. The scarcity of woodchucks and skunks on the upland also handicaps rabbits because of the resulting lack of burrows for winter use.

Because of the insufficiency of other prey species and escape cover, the cottontail apparently is preyed upon heavily. Rabbits are mainly dependent upon their ability to flee for survival from attacks by predators and it is vitally necessary that they have access to a variety of well dispersed cover. Access to such cover is especially needed by juveniles which are inexperienced in escape and more easily captured.

To provide adequate cover for cottontails on submarginal land with extensive stands of timber, the growth of

brush and succulent herbs could be promoted by small release cuttings (plots of 1 to 2½ acres may be desirable). Large idle fields probably can be improved by a network of strip and spot plantings of pines and shrubs. Such plantings have already been made at a state game area in southwestern Michigan, where about 453,000 trees and shrubs have been planted since this study was completed. Most plantings are irregular strips which meander about over contours to connect existing coverts. An average distance of about 150 to 200 yards between strips (3 or 4 rods wide) and spot plantings seem preferable because rabbits did not utilize wider open areas devoid of nearby escape cover. Such strip and spot plantings provide considerable forest edge which permits cottontails to utilize a greater amount of area, yet be reasonably close to adequate escape cover. As a supplement to such woody cover, sweet clover is excellent (Haugen, MS).

Good results in survival have been obtained in southern Michigan on the W. K. Kellogg Bird Sanctuary with local wildlife plantings using false indigobush (*Amorpha fruticosa*), grape (*Vitis* sp.), coralberry (*Symphoricarpos vulgaris*), privet (*Ligustrum ibota*), honeysuckle (*Lonicera morrowi*, *L. tartarica*), snowberry (*Symphoricarpos racemosus*), black locust (*Robinia pseudoacacia*), buckthorn (*Rhamnus cathartica*), and red mulberry (*Morus rubra*) (Haugen, MS). The bark of false indigobush and sumac are preferred winter food for cottontails at the Sanctuary.

Where possible, the presence of such burrowing animals as woodchucks, skunks, and badgers should be encouraged. Combinations of two or more

of the above mentioned "natural" management measures will afford rabbits a more secure habitat in which to live, and will prove more permanent and economical than attempts to control predators.

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